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Texture gradient in a copper tube at maximum and minimum wall thickness

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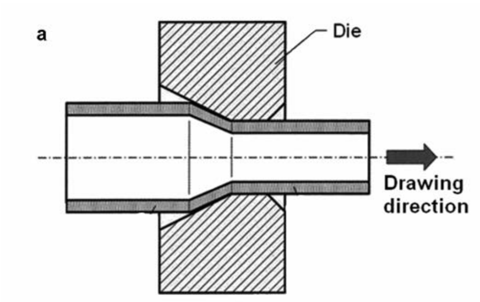
Abstract. Tube drawing is an inhomogeneous process with anisotropic flow. Quantitative texture analysis was used to get inside in eccentricity and ovality of a Cu-tube drawn without a plug. To obtain the texture gradient over the wall thickness high resolution synchrotron radiation was used. One obtains on one hand different textures at the surfaces than in the central region and the other hand a variation of the texture gradient at the maximum wall thickness of the tube compared to the minimum wall thickness.

1. Introduction
Seamless tubes are used for applications where homogeneity of strength, microstructure and extended product life are important design parameters. Cold drawing is widely applied in the industrial production of seamless tubes, employed for various mechanical applications. In order to achieve the final diameter and wall thickness, the extruded pre-tubes are reduced successively in several cold drawing steps. This can be done by just drawing the tube through a die or by adding a plug, which results in better defined wall thickness and inner surface quality. Eccentricity (E), the deviation of the wall thickness over the circumference of the tube from its average value, of pre-tubes causes non homogeneous deformation over the circumference in the single drawing steps.
Texture investigations were carried out at the high energy materials science beamline HEMS P07B at Petra III/DESY-Hamburg. Synchrotron radiation was used because of the high penetration power and the high brilliance. From the texture side it is known that tube drawing produces monoclinic sample symmetry due to a complex deformation process. Based on the process parameters reduction is a combination of reduction in wall thickness and in tube diameter. Most tube investigations were carried out at zircaloy tubes, which are based on the importance of zircaloy tubes in nuclear industries [1,2,3]. A good introduction in this topic is given by Tenckhoff [4]. Investigations on Cu tubes become recently of more interest [5]. But there is a lack of texture gradients investigations on tubes.

2. Sample description
The test sample, made of SF-Cu: 99.90 % min Cu, 0.015-0.040 % P, was a seamless tube produced by drawing without a plug as a final deformation step, see figure 1a. The pre-tube obtained by extrusion was reduced in several cold drawing steps to its final dimension. In a first step a ring of 4mm length was cut from the drawn Cu-tube. Due to the variation of the wall thickness three small cubes were prepared with cross section of about 4x4 mm², one at maximum thickness, one at minimum thickness and one at medium thickness position, see

figure 1b. It should be noticed that a sample cut will not change the crystallographic texture but the stress state.



b

Parameter		Pre-tube	Final tube
Outer Ø d	(mm)	50.0	40.9
Average thickness t	(mm)	4.2	4.37
Δ thickness Δt	(mm)	0.8	0.65
Eccentricity E	(%)	9.5	7.4

Fig. 1: Plug-less drawing (a) and geometrical data of the final tube (b) over tube wall thickness

3. Experiment

Pole figure measurements were carried out at the high energy beamline HEMS-PO7B@Petra III/Hasylab - Hamburg with an energy of 86,76 keV. The wavelength of 0.1430 Å, equivalent to 86,76 keV, was much lower than standard CuKα X-rays with 1.5418 Å of laboratory X-rays. Basic advantages of the lower wavelength are on one side a much higher penetration power and on the other side very low scattering angles to obtain complete Debye-Scherrer rings. For this purpose a set of complete pole figures were obtained without sample tilt [6]. A typical set up to optimize the counting time for overnight measurements is shown in figure 2, in which three small samples have been glued together. Based on prior experiments with only three positions over the wall thickness nine positions were scanned to obtain the texture gradient more precize. A beam size of 300x500μm² (figure 2), gives a sufficient local resolution. For one sample position the total pole figure measurement consists of 37 area detector images, each of them lasted 20 sec.

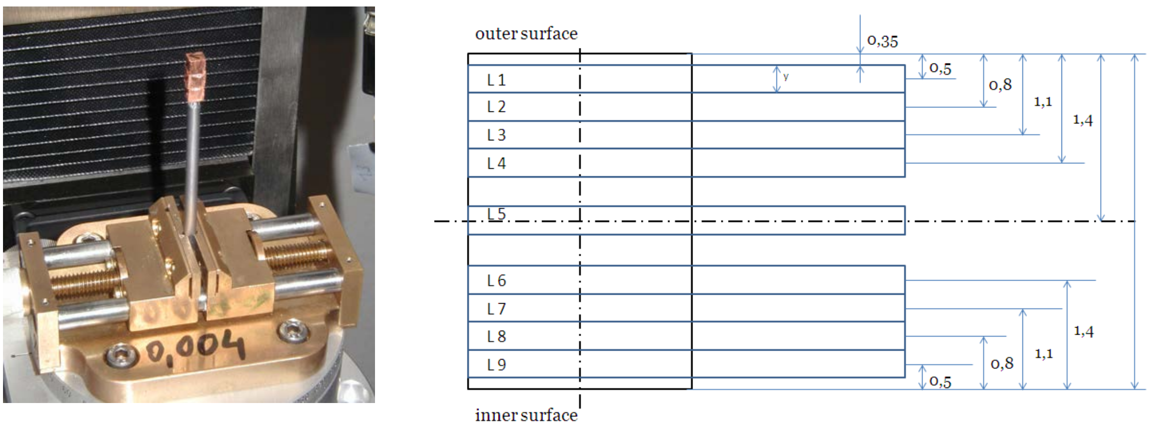


Fig. 2: Samples mounted on a pin and technical drawing of measured positions

4. Results

Quantitative texture was calculated firstly by extracting the pole figure data from area detector data by the software package SABO for three Cu reflections (111), (200) and (220). Thereafter the iterative series expansion method after Bunge was used to obtain the orientation distribution function (ODF). All steps were done with triclinic sample symmetry. As an example, figure 3 presents the φ2=45° ODF sections for the outer surface (L1), the

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inner surface (L9) and the central position (L5) for two samples. As expected the texture gradient at maximum wall thickness is similar to the texture gradient at minimum wall thickness.

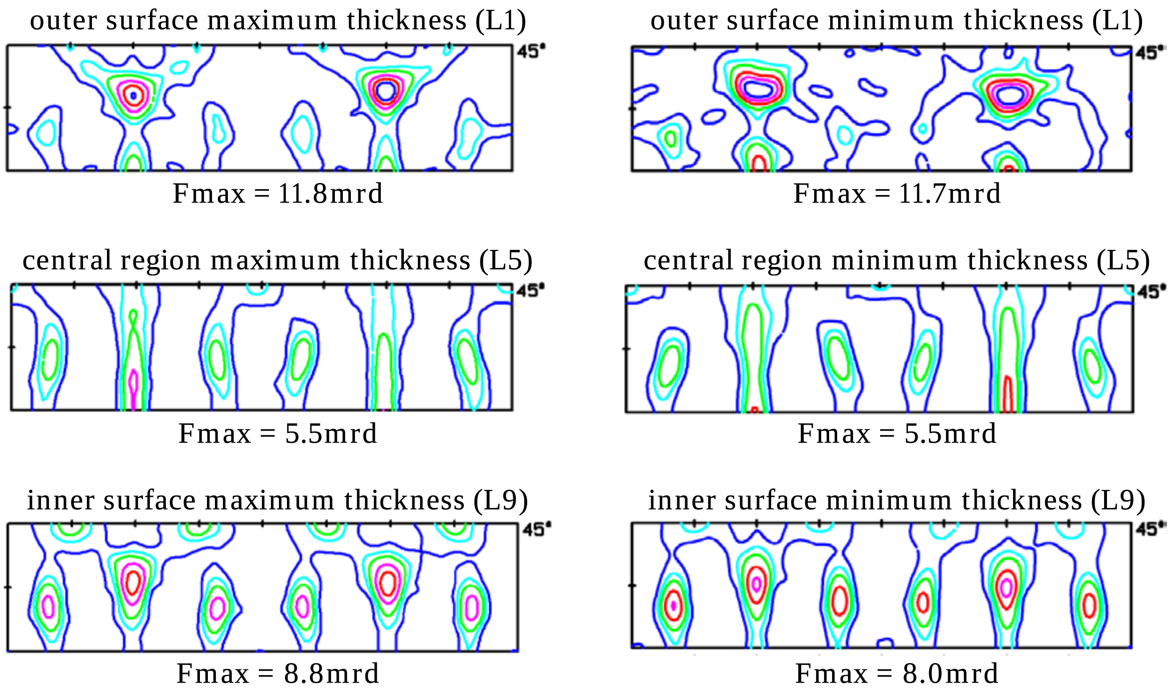

Fig. 3: ODF sections φ2=45° at outer surface, central position and inner surface

Comparing with ideal texture components and texture fibers in the orientation space (figure 4) one can see that the τ-fiber <110>//TD dominates the texture evolution with a strong variation from outer region to inner region for both samples. Particular at the inner surface (L9) a weak cube component is present, while at central position (L5) shows a minor rotated cube. Another texture component at φ1=30° to 35°,Φ= 55° to 60°, φ2=45° which is close to the γ-fiber shows a remarkable gradient from outer to inner surface.

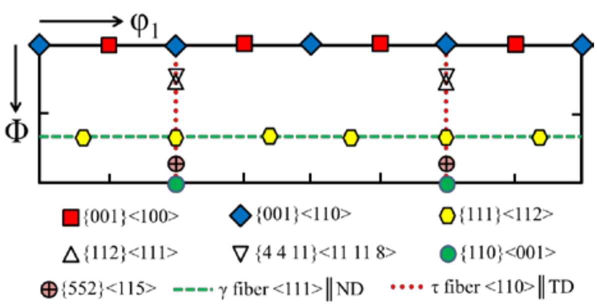

Fig. 4: Ideal texture components and texture fibers in ODF sections φ2=45°

The comparison of the two texture components at φ1=30°, Φ=60°, φ2=45° ({111}<112>) and φ1=45°, Φ=0°, φ2=45° ({001}<100>) shows for maximum thickness and for minimum thickness the same tendency (figure 5). One difference is a stronger cube component at both surfaces (L1 and L9) for the sample at maximum wall thickness. The ({111}<112> is little stronger at the inner surface (L9) for minimum wall thickness with 7.2 mrd against 5.8mrd.

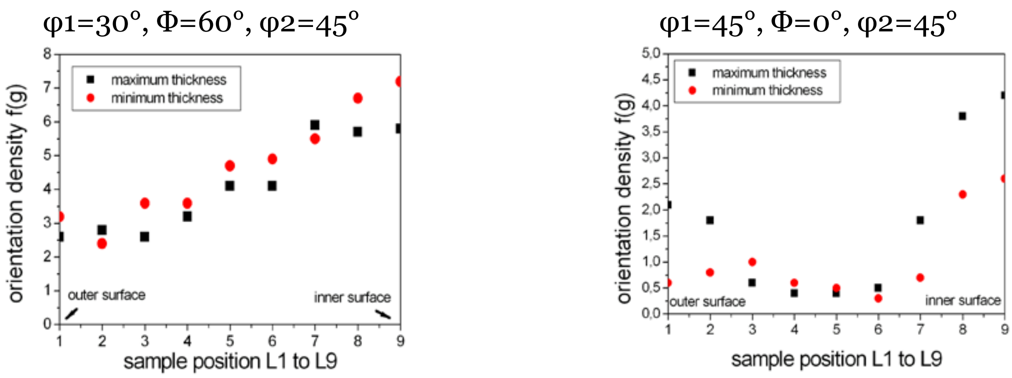

Fig. 5: Texture gradient of components φ1=30°, Φ=60°, φ2=45°and φ1=45°, Φ=0°, φ2=45°

The τ-fiber evolution has been discussed intensively by Hirsch et al. [7] for Cu30%Zn with different rolling degrees. There is a shift of the Cu-component to higher Φ-values which goes faster at maximum thickness than on minimum thickness. Strongest texture is at the outer surface while in the central region a much weaker texture exists.

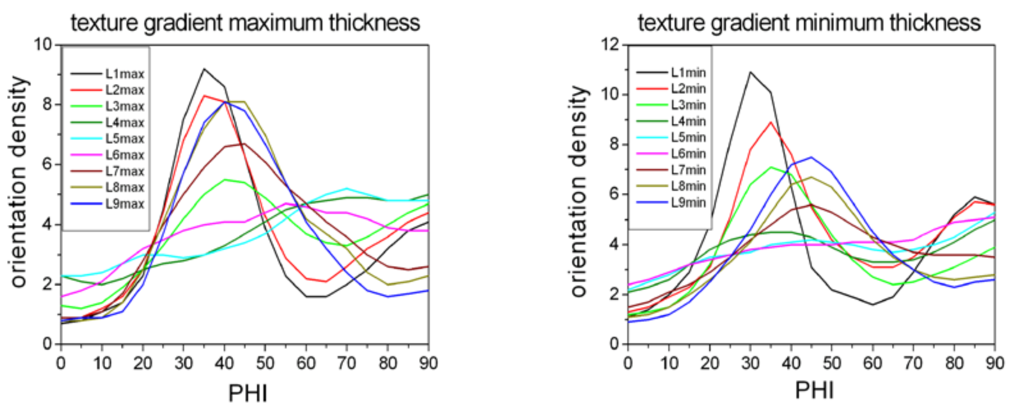

Fig. 6: τ-fiber evolution

It should be noticed that a correlation between texture gradient and tube drawing parameters needs more experiments including the initial texture.

References

[1] Vicente Alvarez M A, Santisteban J R, Domizzi G and Almer J 2011 *Acta Mat.* **59** 2210
[2] Mareau C and Daymond M R 2011 Mater. Sci. Eng. A **528** 8676
[3] Li Y, Rogge R and Holt R A 2006 Mater. Sci. Eng. A **437** 10
[4] Tenckhoff E 1980 *Verformungsmechanismen, Textur und Anisotropie in Zirkonium und Zirkaloy* (Berlin Gebrüder Bornträger Verlag)
[5] Carradò A, Brokmeier H-G, Pirling T, Wimpory R, Schell N and Palkowski H 2013 *Advanced Eng. Materials* **15** 469
[6] Brokmeier H-G and Yi S B 2008 *Texture and Texture Analysis in Engineering Materials* (Neutrons and Synchrotron Radiation in Engineering Materials Science) eds W. Reimers, A. Pyzalla, A. Schreyer, H. Clemens (Weinheim Wiley VCH Verlag) chapter 10 pp.57-77
[7] Hirsch J, Lücke K and Hatherly M 1988 *Acta metal* **36** 2905